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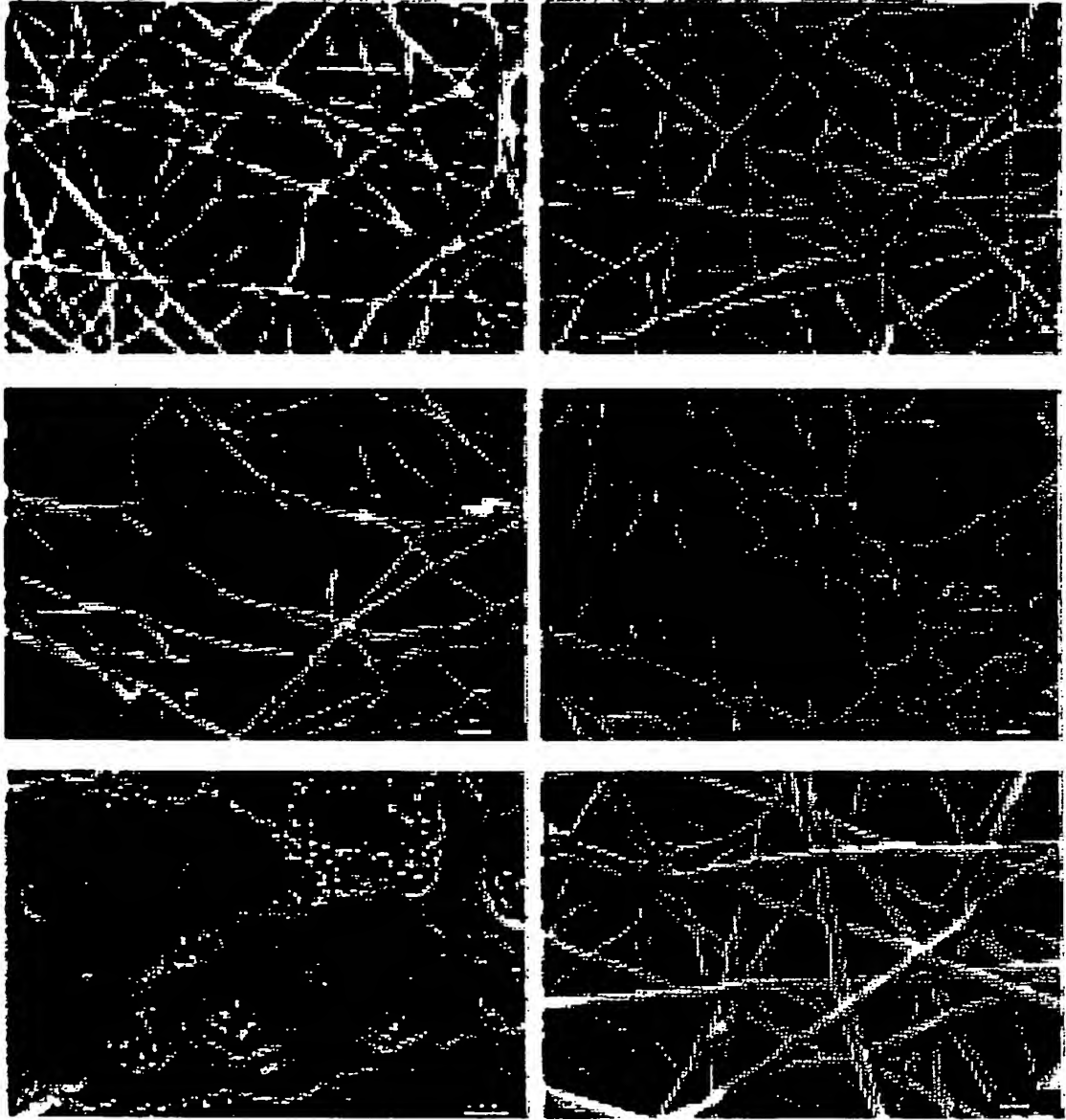
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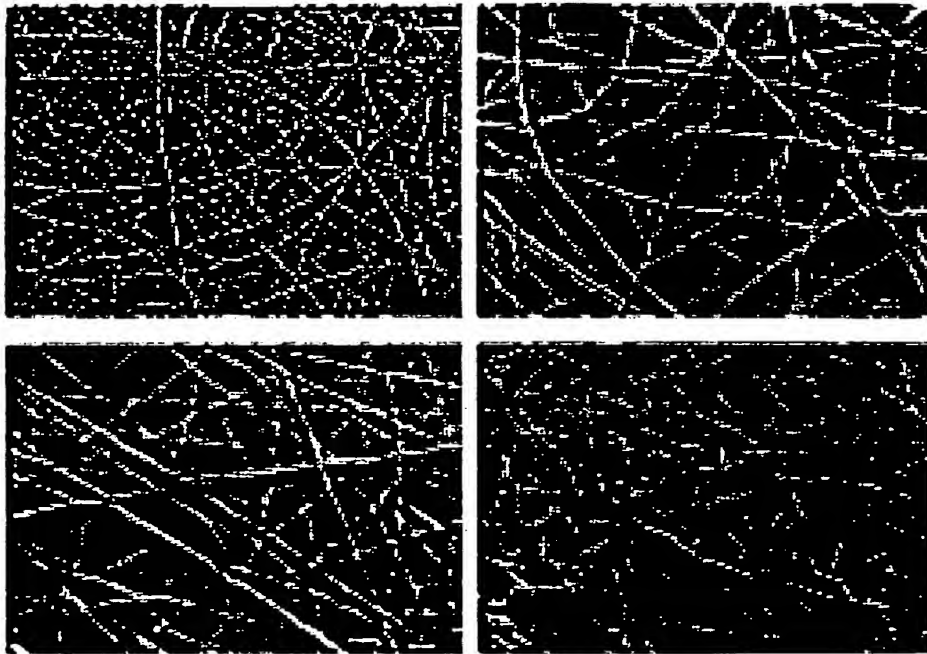
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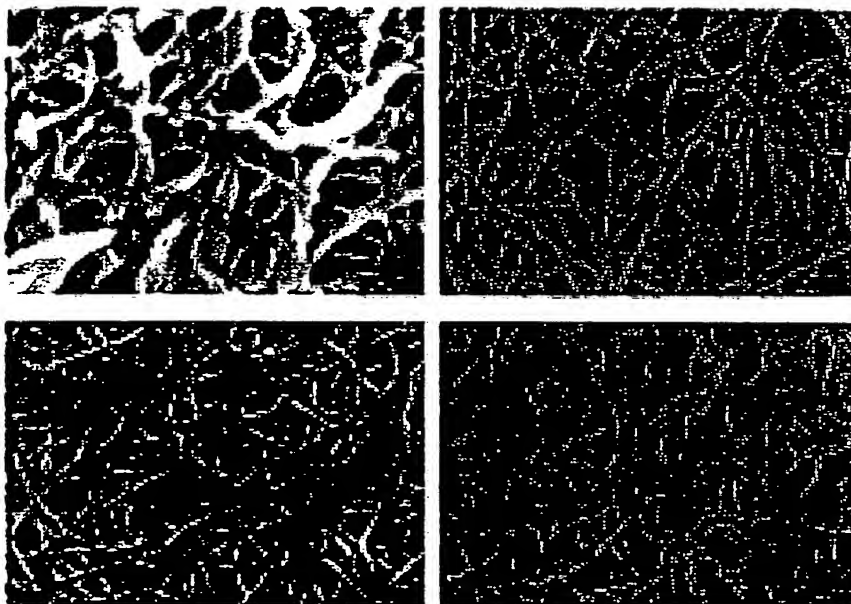
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**FIG. 1**



**FIG. 2**



**FIG. 3**

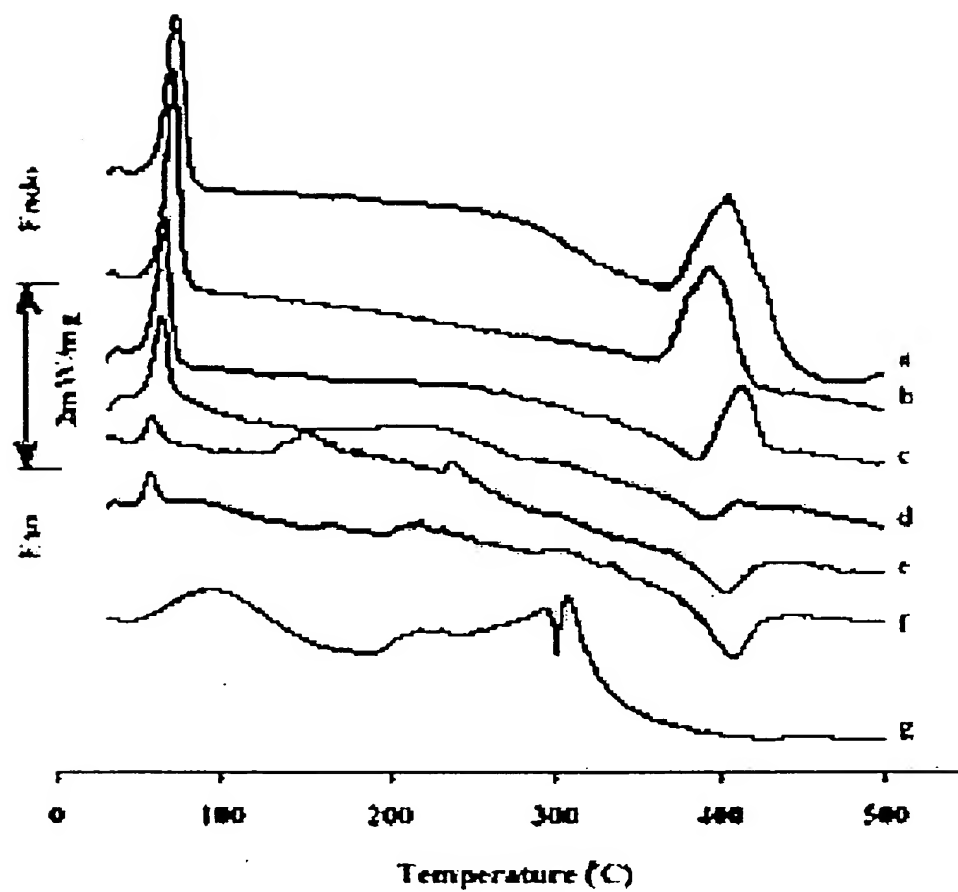


FIG. 4

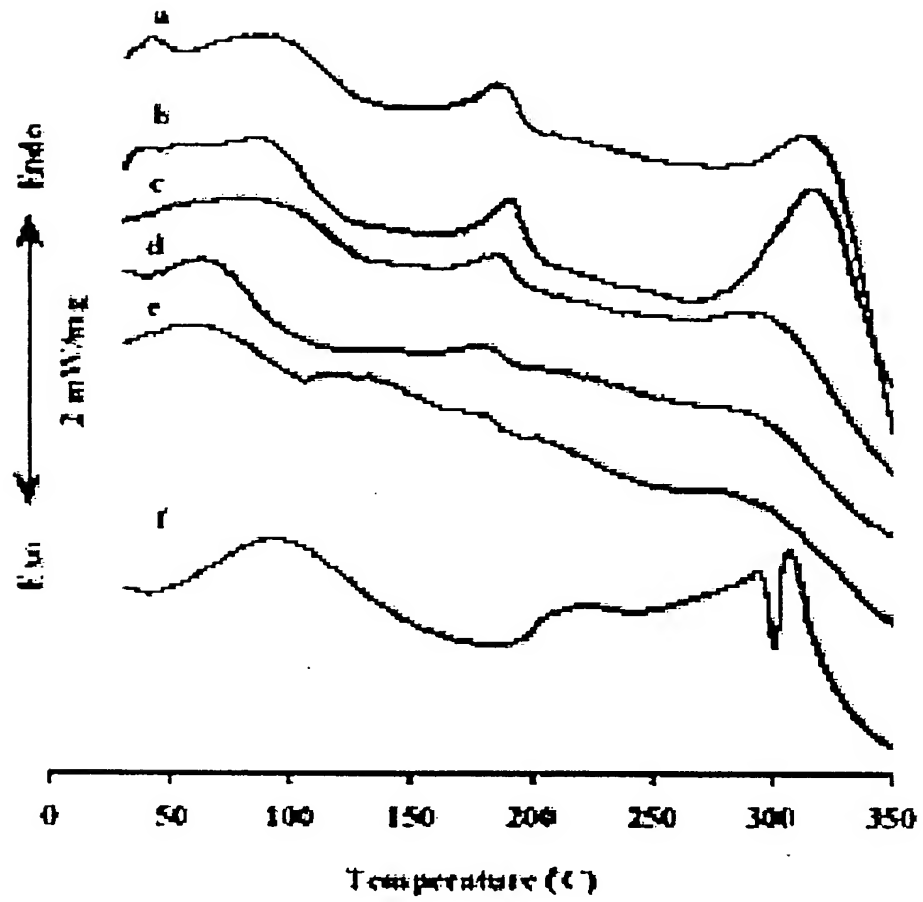


FIG. 5

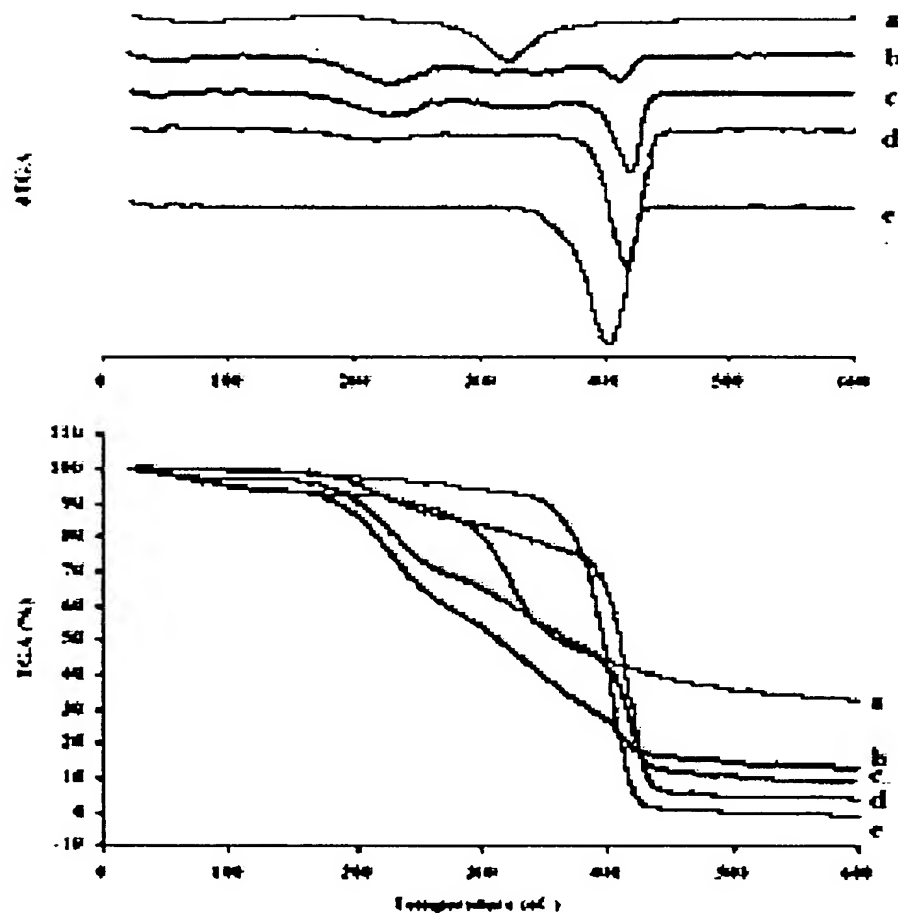


FIG. 6

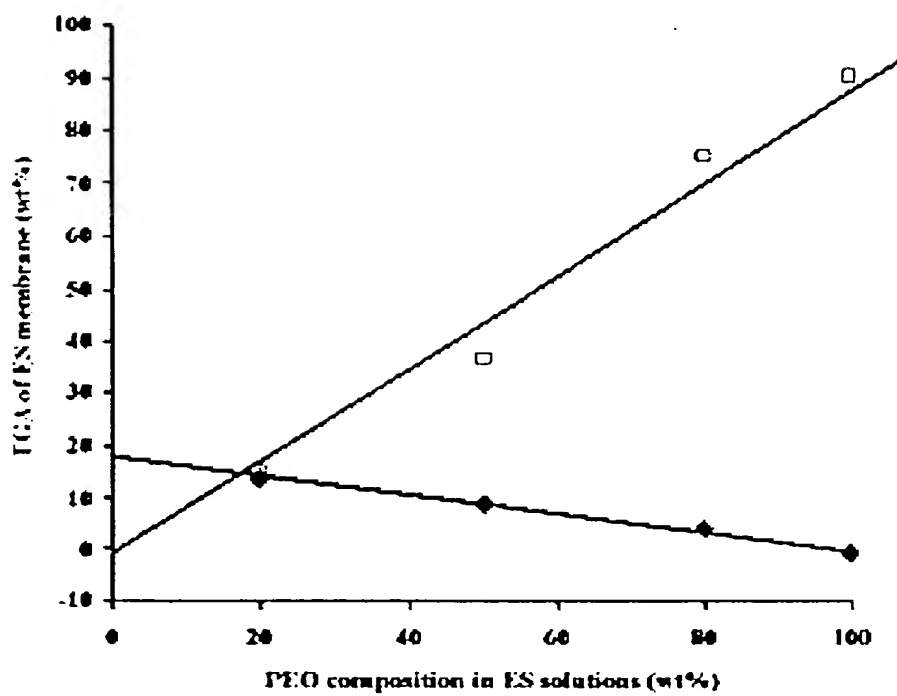


FIG. 7



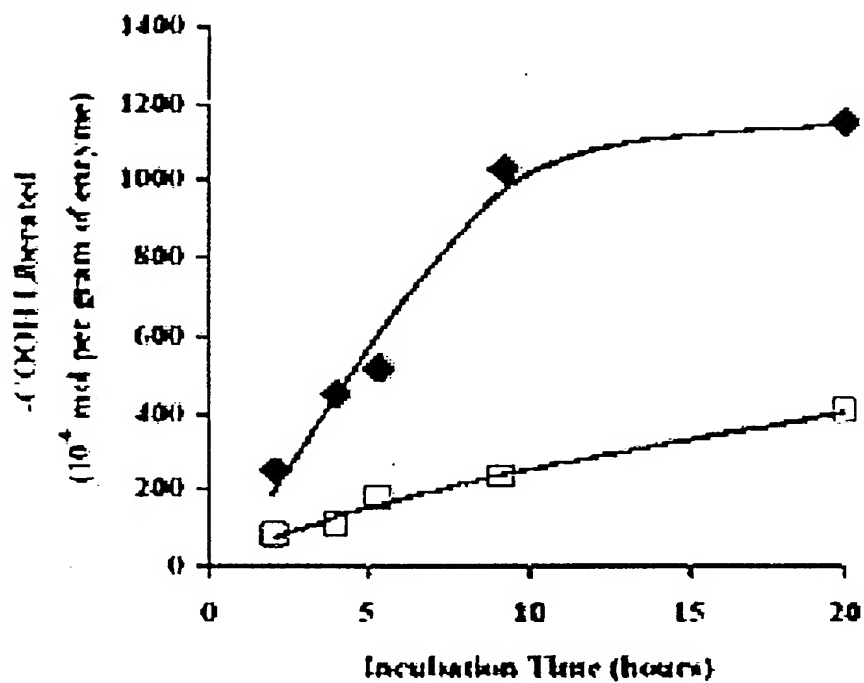


FIG. 8

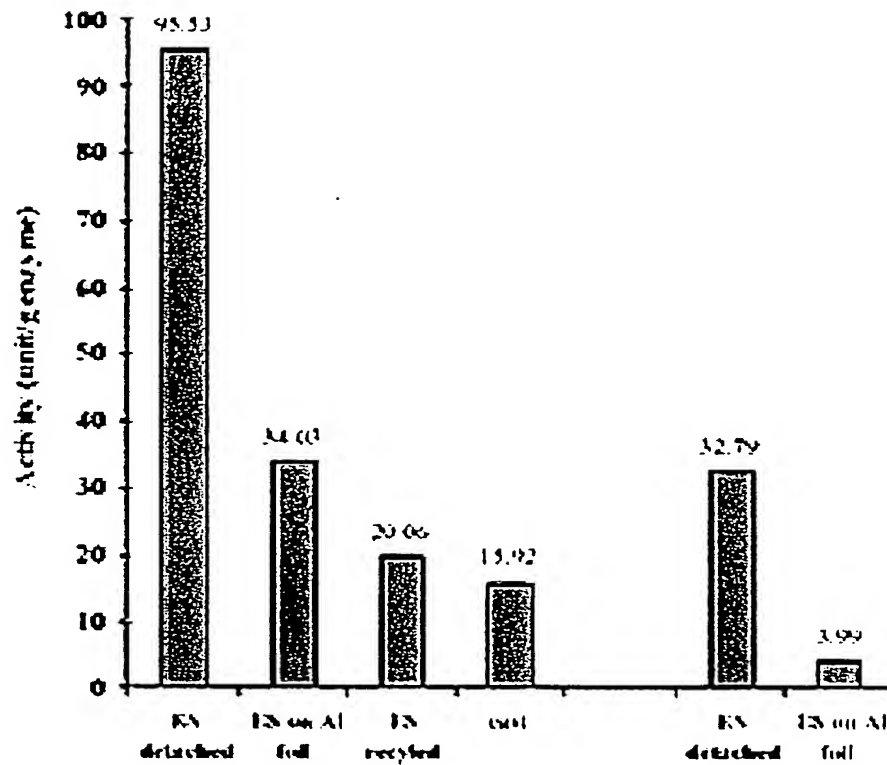


FIG. 9

*Reactive Groups on Proteins*

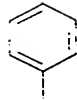
<u>Reactive group</u>	<u>Amino Acid</u>	<u>pKa</u>
-NH <sub>2</sub>	Lysine( $\epsilon$ -NH <sub>2</sub> ),N-terminal amino groups ( $\alpha$ -NH <sub>2</sub> )	10.53;9.0-9.9
-COOH	Asparate,Glutamate,C-terminal carboxyl groups	3.86;4.07;1.8-2.4
-SH	Cysteine	8.27
-SS-	Cystine	—
	Tyrosine	10.07

FIG. 10A

# *Reactions with Protein Amine $NH_2$*

<i>Reactive groups</i>	<i>Coupling Reaction</i>
<i>Acid anhydride</i>	<i><math>(CO)_2O</math> Peptide formation</i>
<i>Isocyanate</i>	<i><math>NCO</math> Peptide formation</i>
<i>Acylchloride</i>	<i><math>COCl</math> Peptide formation</i>
<i>Oxirane</i>	<i><math>OCHXCH_2</math> Alkylation</i>
<i>Aldehyde</i>	<i><math>CHO</math> Schiff base</i>

FIG. 10B

# Amphiphilic Spacer

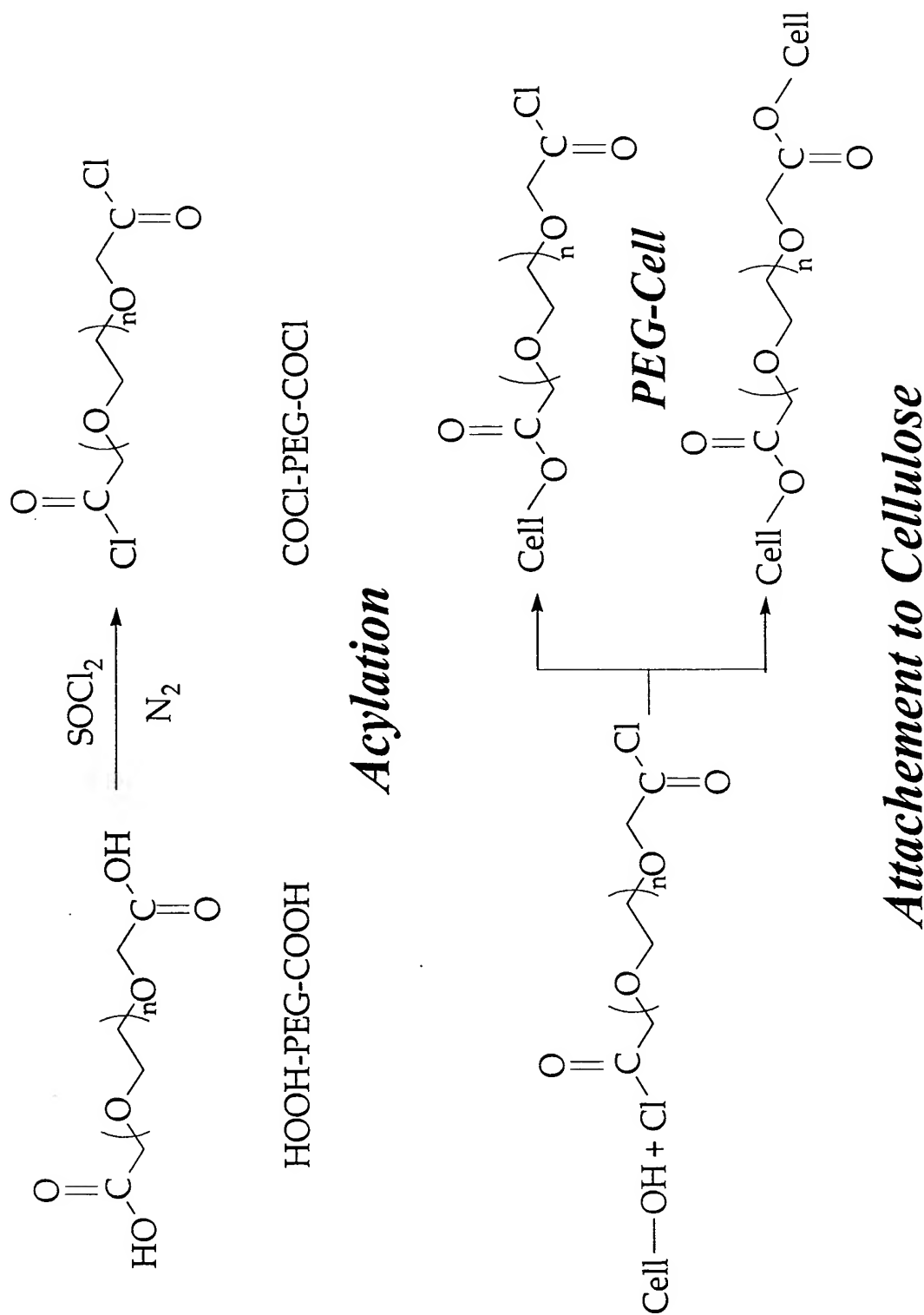


FIG. 11

*Cellulose and PEG-Cell Fibrous Membranes*  
*Total Ester and Carboxyl Acid vs Free Acid*

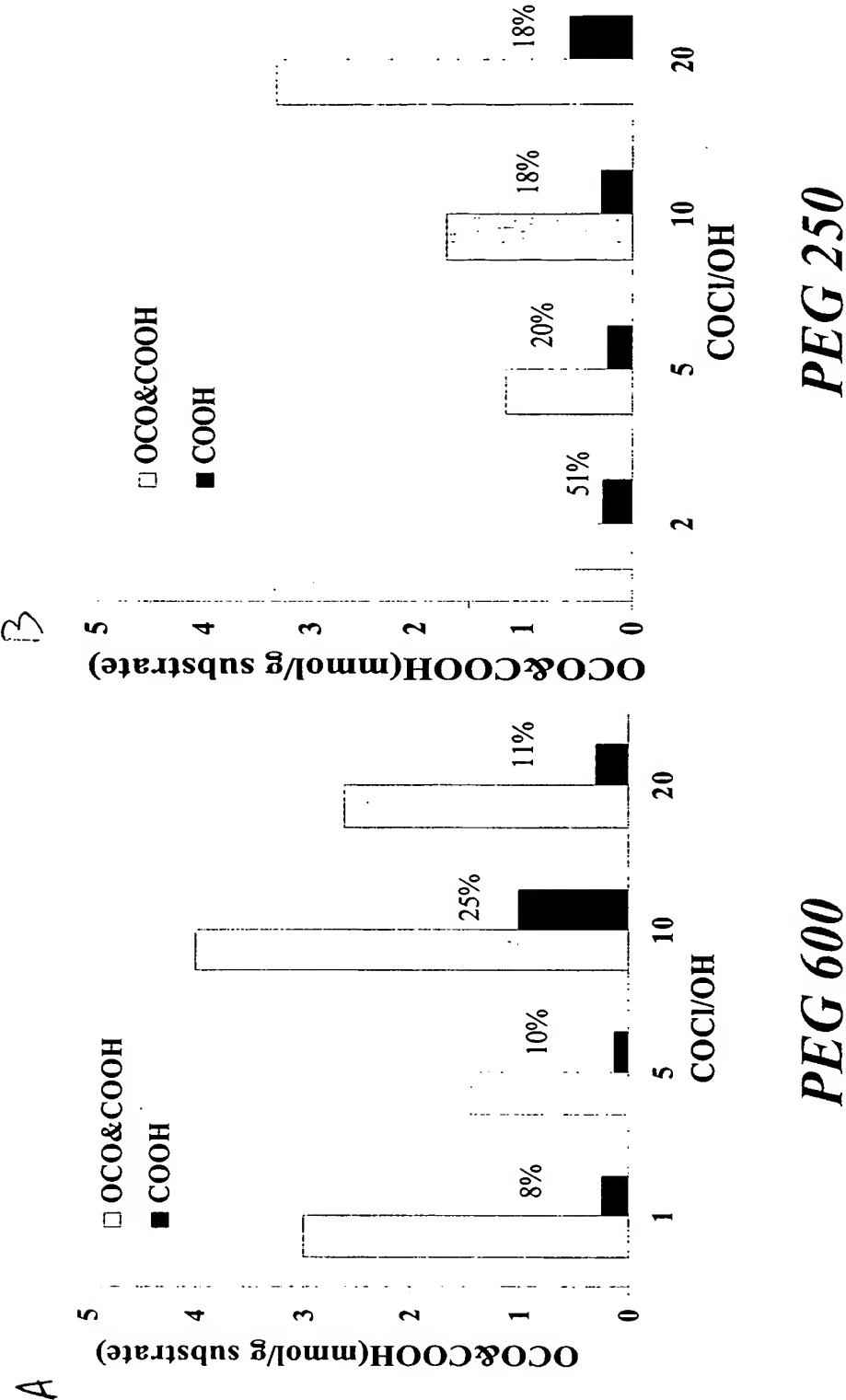
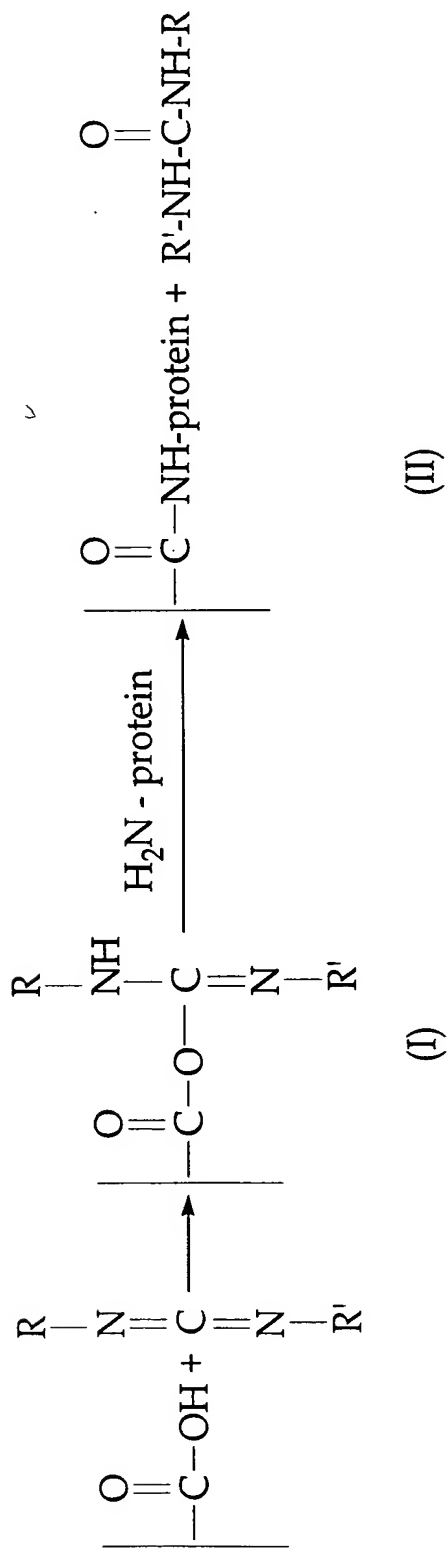


FIG. 12

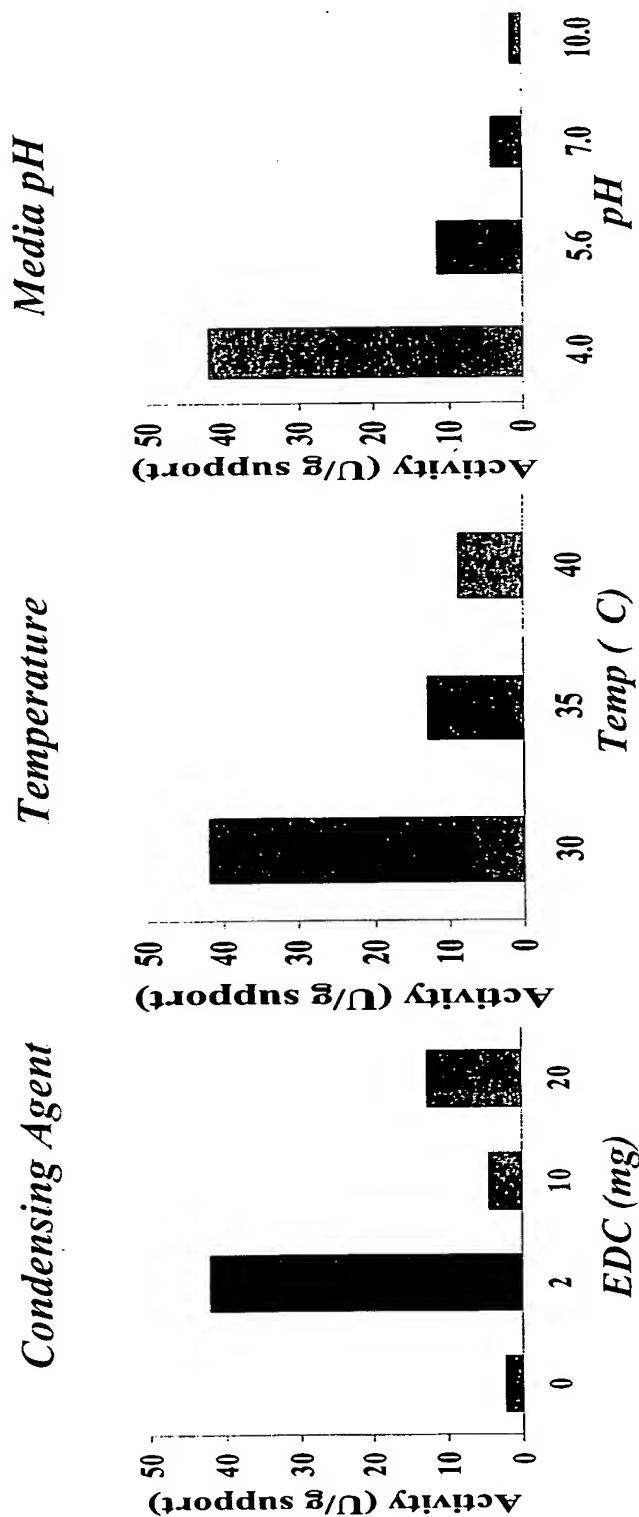
# *Coupling of Protein Amine and PEG-Cell Carboxylic via Carbodiimide*



R, R' = CH<sub>2</sub>CH<sub>3</sub>, CH<sub>2</sub>CH<sub>2</sub>CH<sub>2</sub>-N(CH<sub>3</sub>)<sub>2</sub>

FIG. 13

# *Lipase-PEG-Cell Fibrous Membranes -Coupling Reaction Conditions-*



*pH 4.5; 30°C      2 mg EDC; pH 4.5      2 mg EDC; 30°C*

*50 mg PEG-CELL support (PEG 600, 10 COCl/OH); 5 mg lipase;*

*5 ml aqueous buffer; 7 h.*

FIG. 14



# *Lipase-PEG-Cell Fibrous Membranes -varying COCl/OH ratios and PEG lengths-*

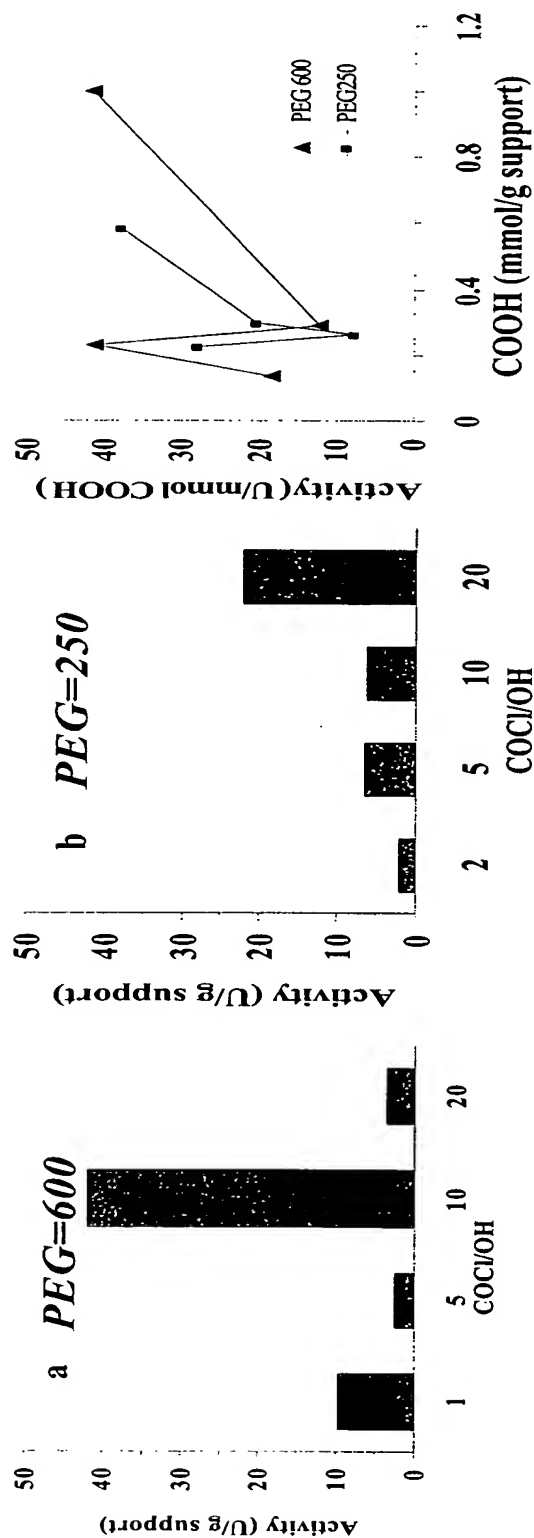
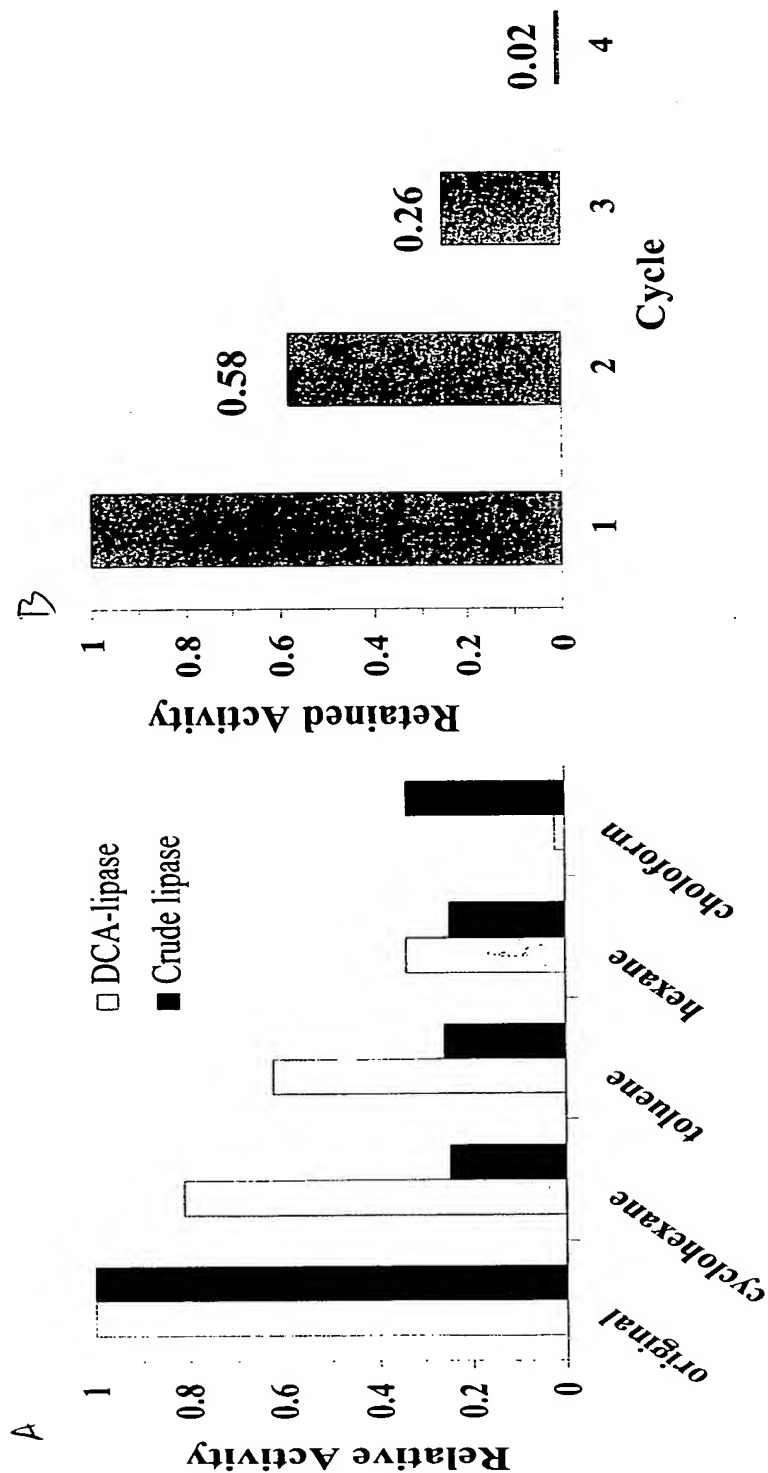


FIG. 15

**50 mg PEG-Cell support; 5 mg lipase; 2 mg EDC;  
 5 ml aqueous buffer (pH 4); 7 h, 30°C.**

# *Lipase-PEG-CELL Fibrous Membranes* *Stability and Reusability*



50 mg PEG-Cell support (PEG250,  
 20 COCl/OH); 5 mg lipase; 2 mg  
 EDC; 5 ml pH 4 buffer; 7 h, 30°C.

50 mg PEG-Cell support (PEG600,  
 10 COCl/OH); 5 mg lipase; 2 mg  
 EDC; 5 ml pH 4 buffer; 7 h, 30°C.

FIG. 16



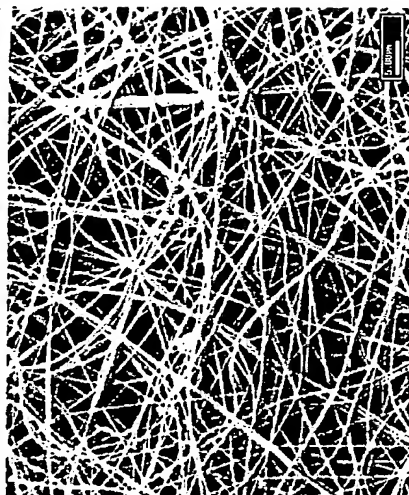
ES Cellulose Acetate				<u>Fiber</u>	<u>Pore Volume</u>		
DS=2.45, 30,000Dalton 2:1 Acetone/DMAc					<u>Total</u>	<u>Planar</u>	
<u>Target</u>	<u>Conc.</u>	<u>Porosity</u> $\phi$		<u>Diameter</u> nm	$C_m$ $\mu\text{ll/mg}$	$C_v$ $\mu\text{ll/mg}$	$C_v/C_m$
Paper	20%CA	0.95		$\leq 3000$	24.8	17.0	0.69
Water	20%CA	0.76		500-3000	6.3	3.1	0.49
Water	15%CA	0.43		100-500	3.0	1.0	0.33

FIG. 17

# Ultra-fine Cellulose Fibers Hydrolysis and Methacrylation

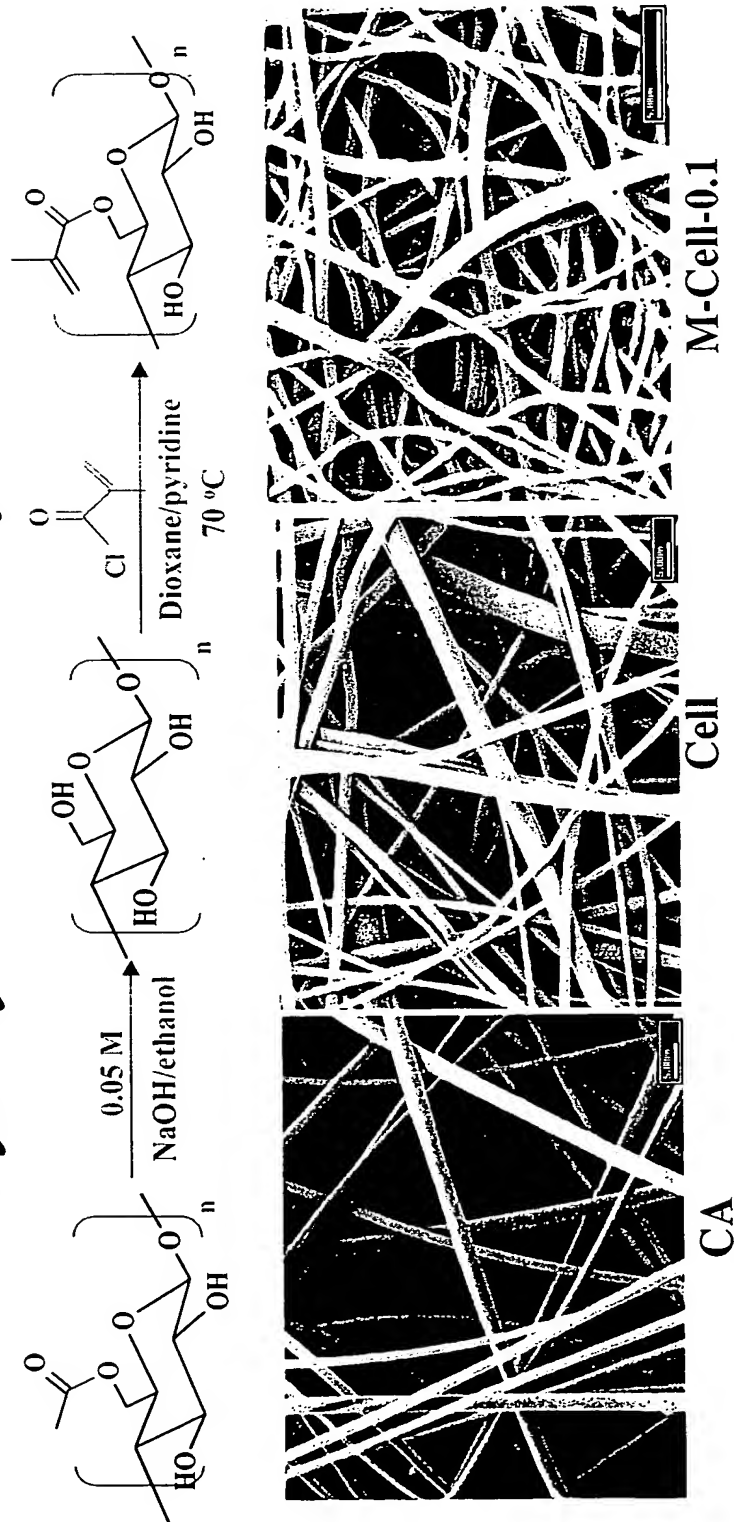


FIG. 18

	CA	Cell	M-Cell-0.1
$\theta_{H_2O}$ ( )	84	56	84
$C_m$ (ul/mg)	17.0	5.2	4.9
$C_{H_2O}$ (ul/mg)	0	13.0	4.3

# *Poly(acrylic acid) Brushes on Ultra-fine Cellulose Fibers*

## *I. FR Polymerization on M-Cell*

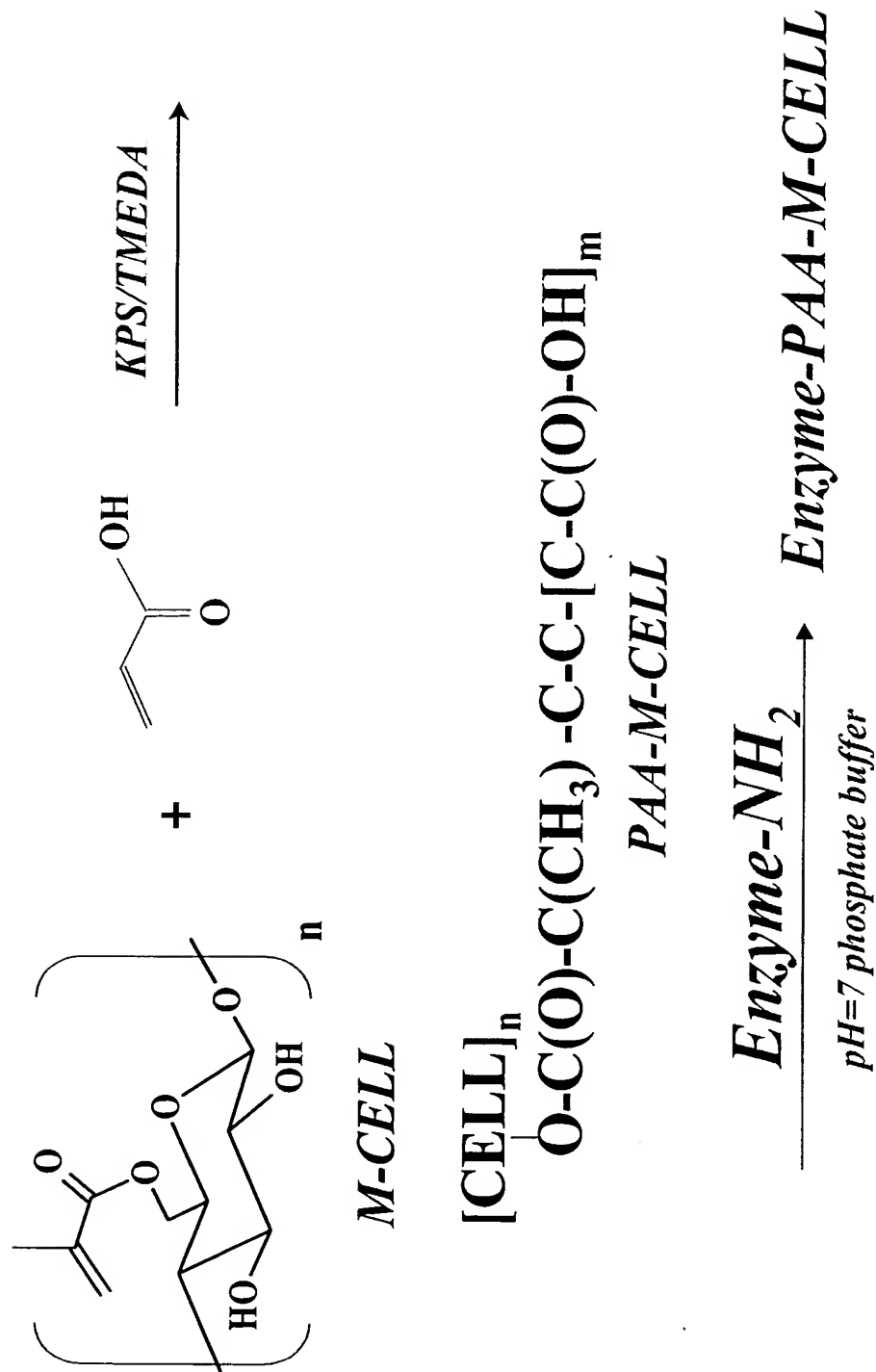
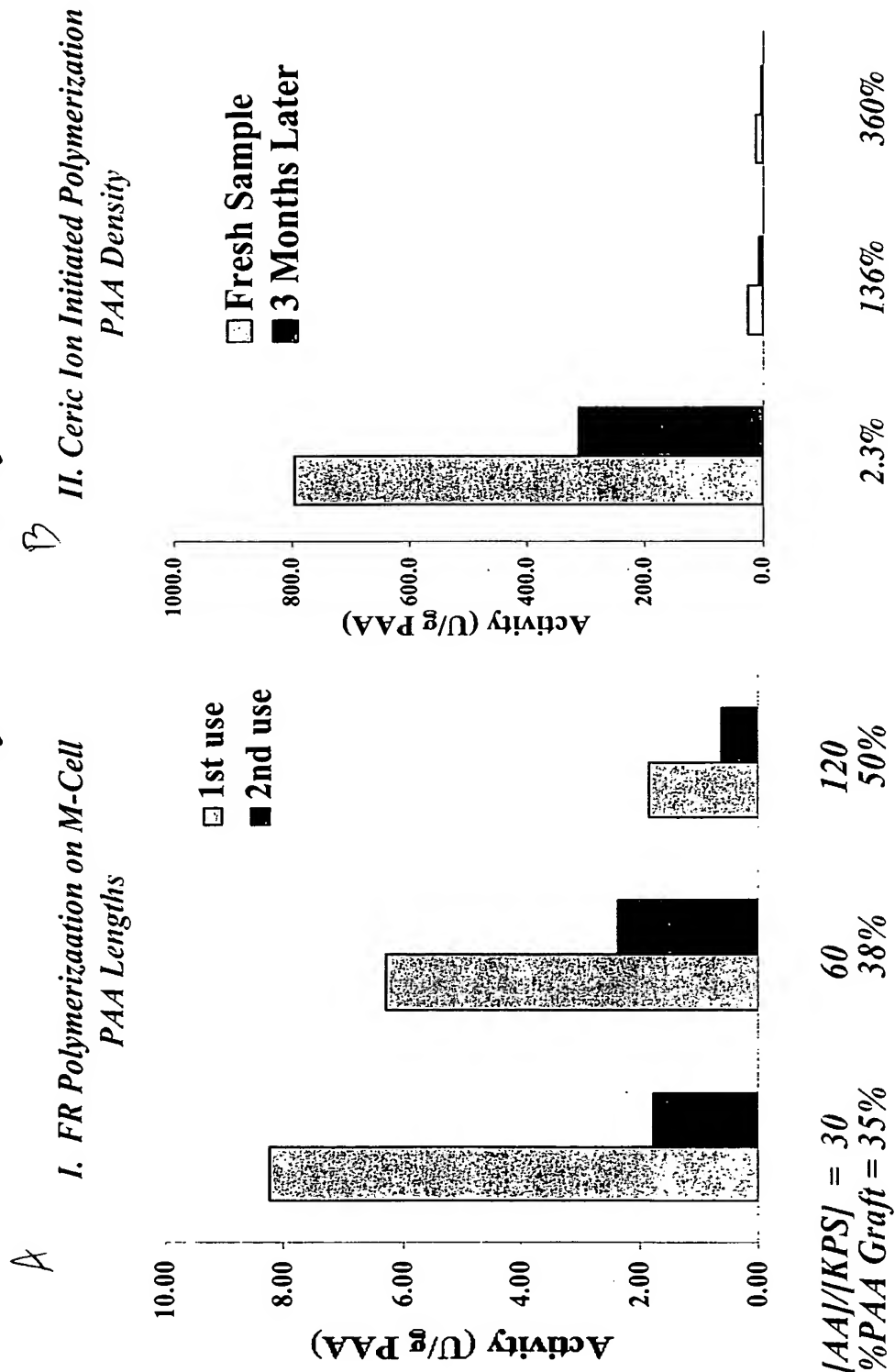


FIG. 19

# Poly(acrylic acid) Brushes on Ultra-fine Cellulose Fibers

## Enzyme\* Activity



\*Lipase from *Candida rugosa* (Sigma, EC 3.1.1.3, type VII)

FIG. 20

# *Poly(acrylic acid) Brushes on Ultra-fine Cellulose Fibers* *II. Ceric Ion Initiated Polymerization*

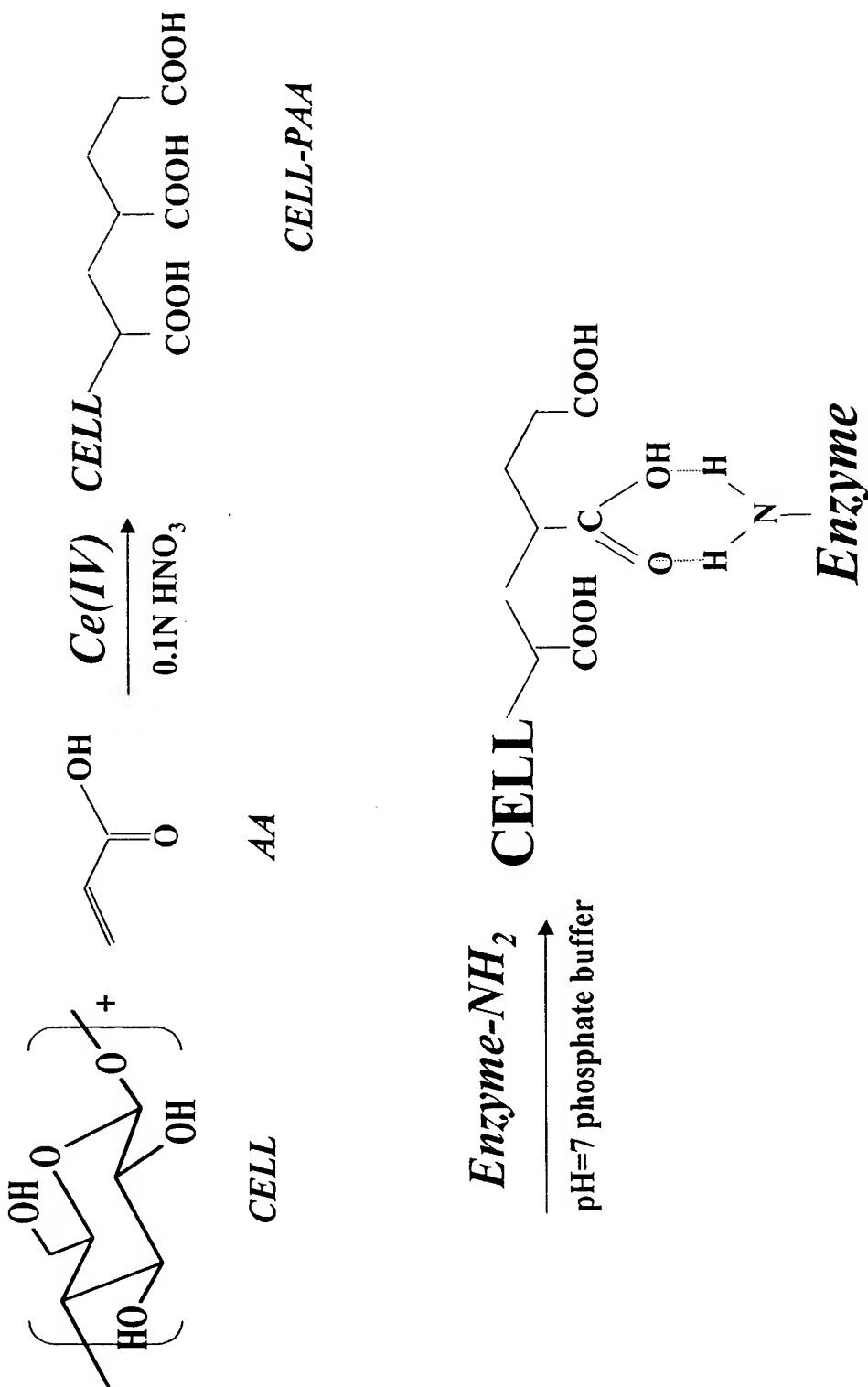
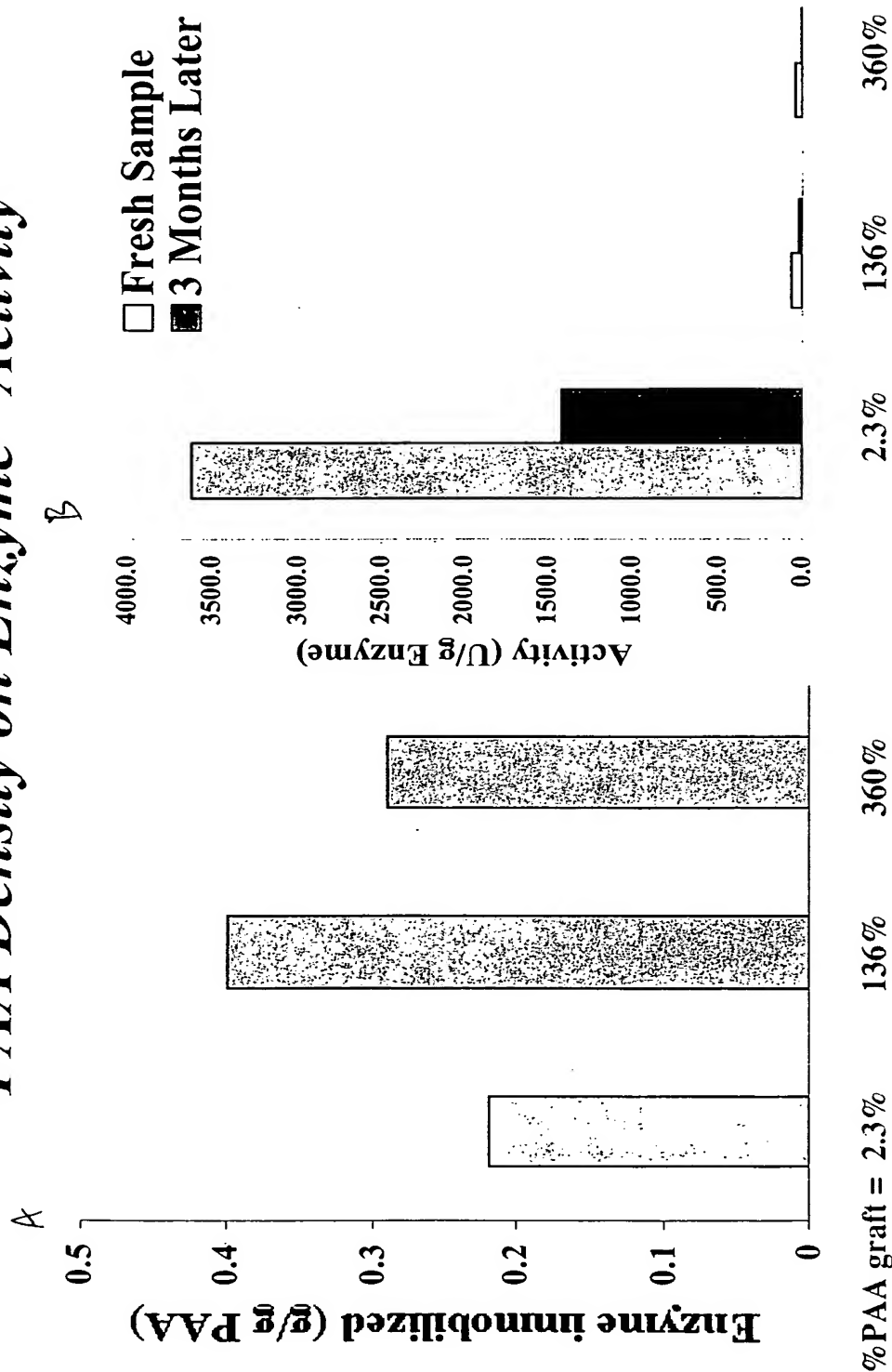


FIG. 21

*Poly(acrylic acid) Brushes on Ultra-fine Cellulose Fibers*  
*II. Ceric Ion Initiated Polymerization<sup>^</sup>*  
*PAA Density on Enzyme\* Activity*

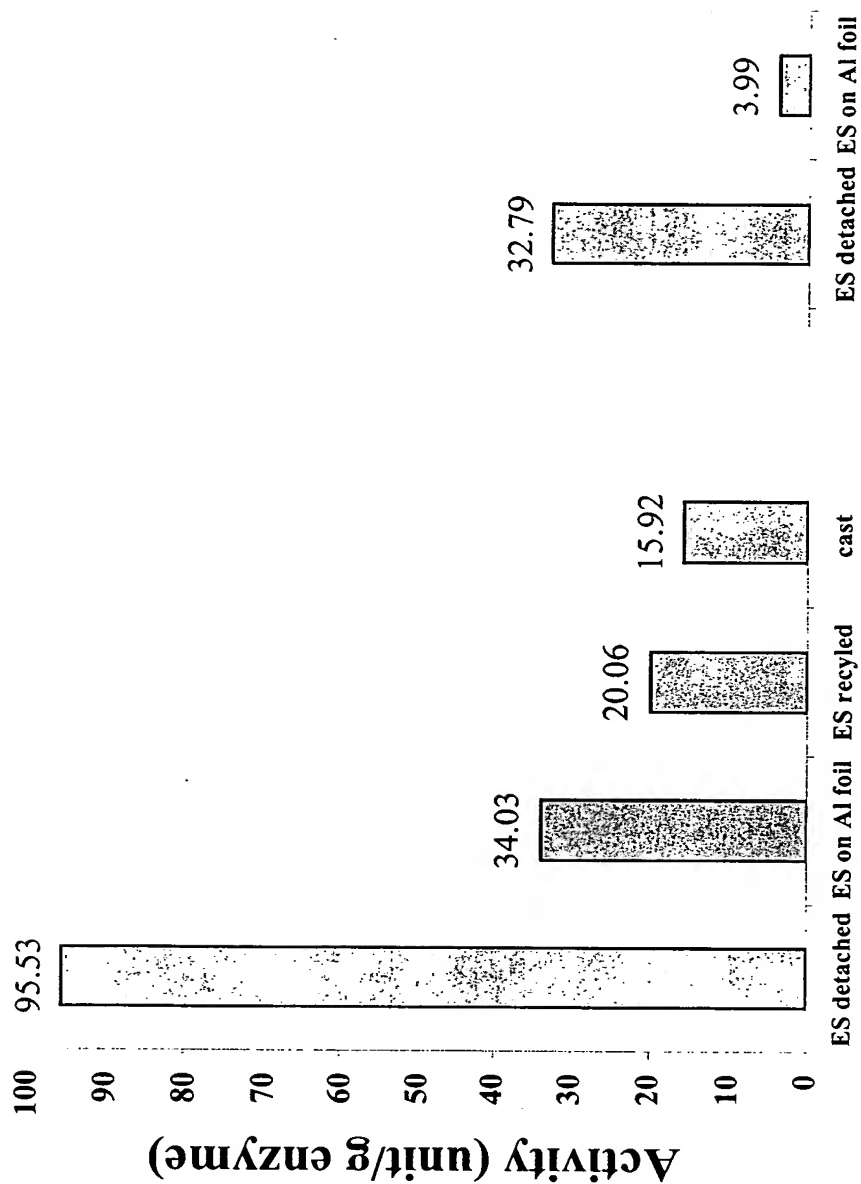


<sup>^</sup> Varying [AA] at const. 120 [AA]/[I]  
\* Lipase from *Candida rugosa* (Sigma, EC 3.1.1.3, type VII).

FIG. 22



# Activities of Enzyme Fibrous Protein Membranes



80:20 PVA:lipase      30:40:30 PEO:casein:lipase  
Lipase from *Candida rugosa* (EC 3.1.1.3, type VII)

FIG. 23

## *Viscosities of Lipase/PVA Solutions*

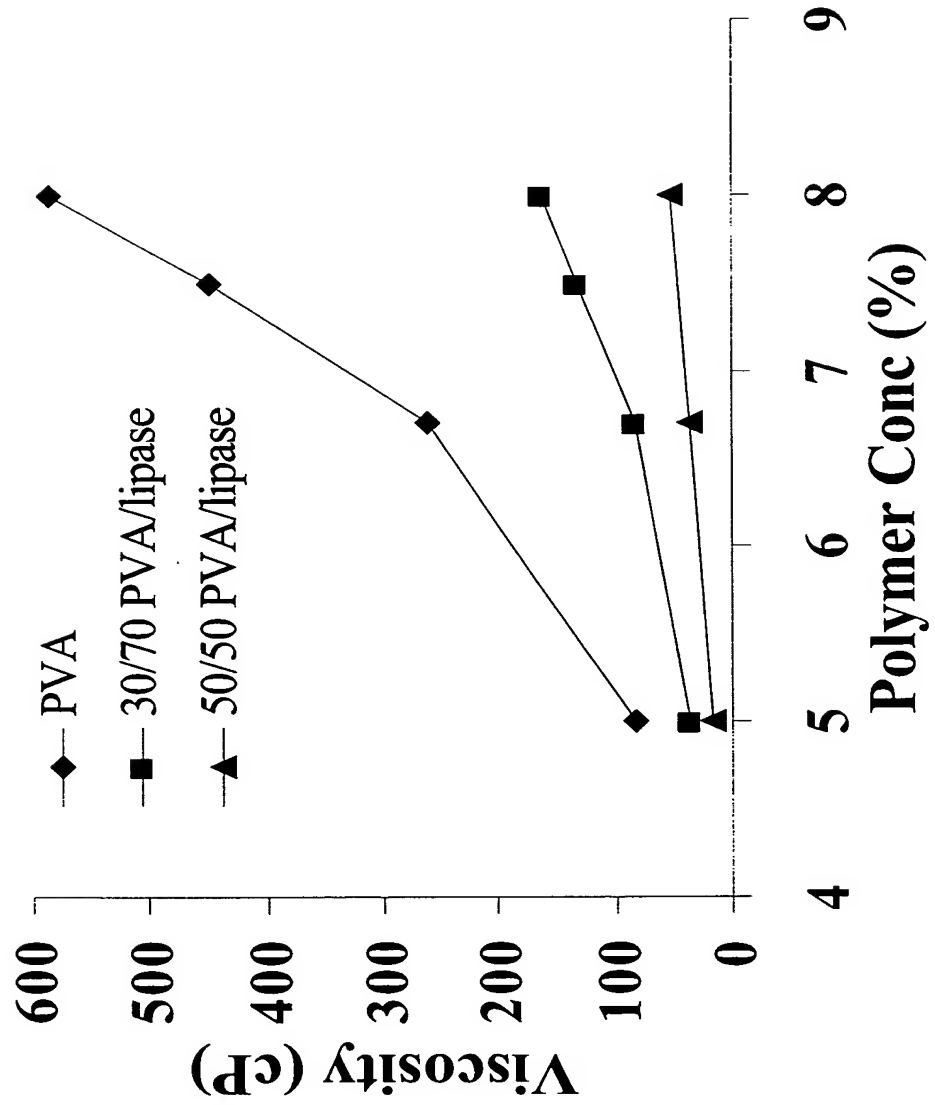


FIG. 24

# *PVA/Lipase Membranes* *Thermal Properties*

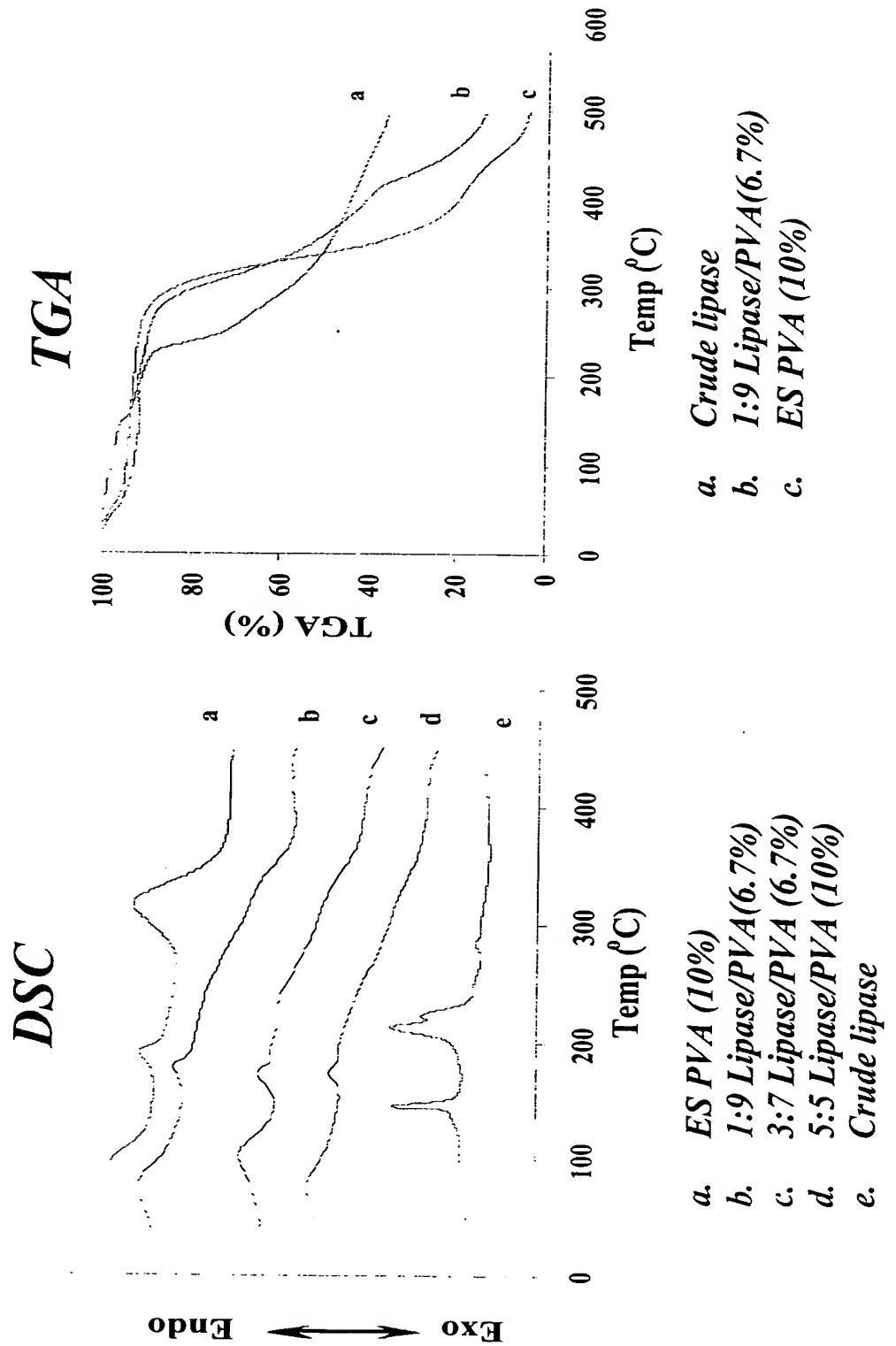
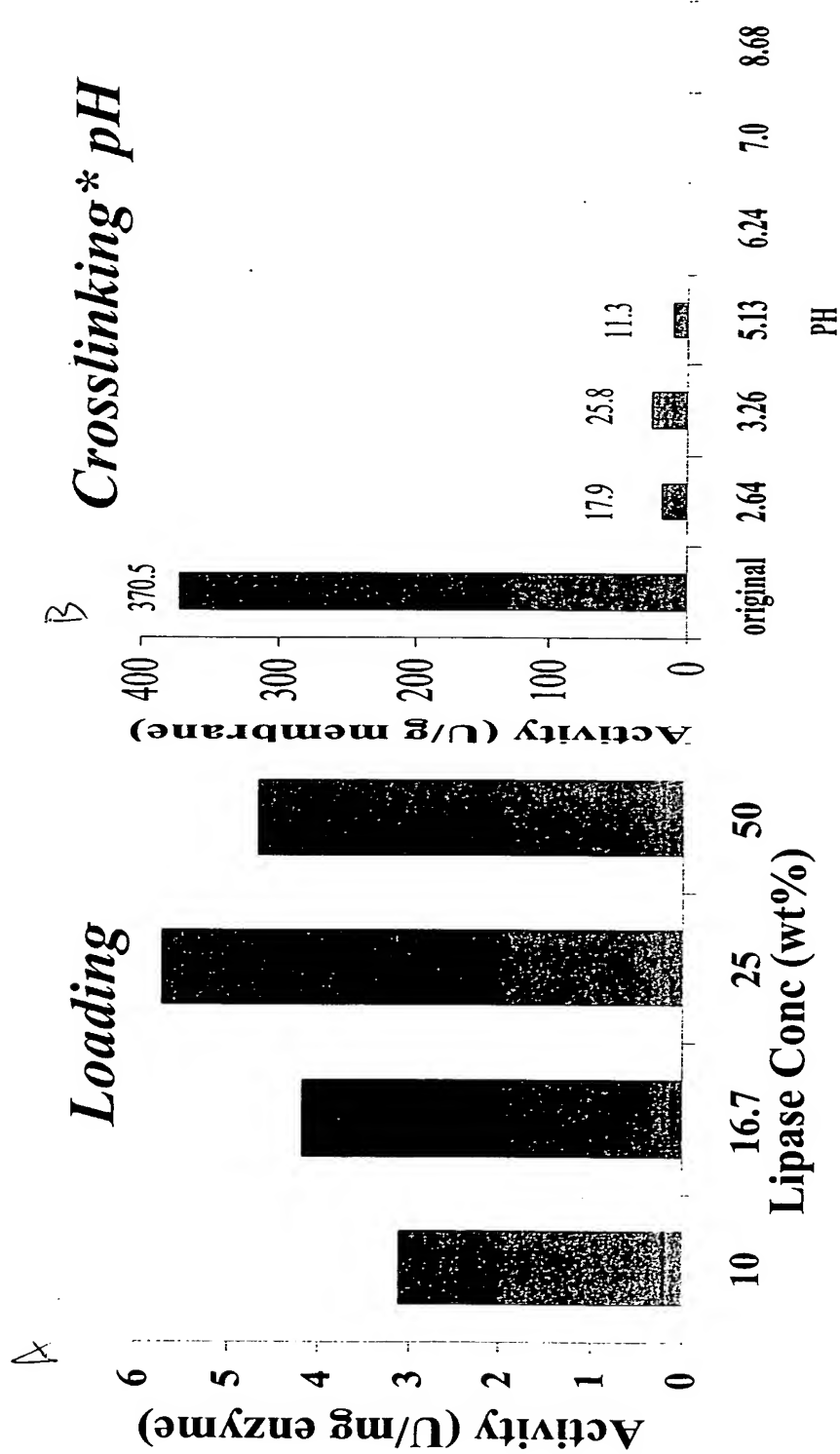


FIG. 25

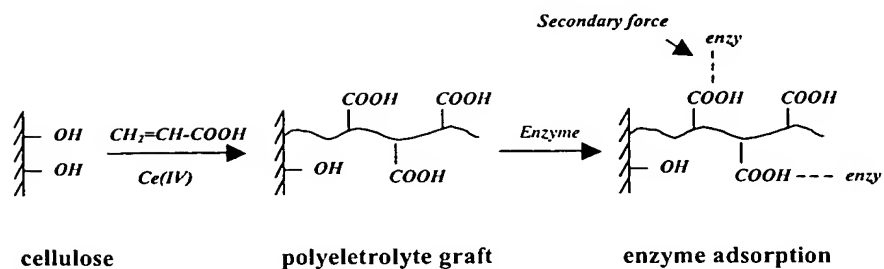
# *PVA/Lipase Membranes<sup>^</sup>* *Enzyme Activity*



<sup>^</sup> 1:9 Lipase/PVA (6.7% aq. soln.)  
\* 0.1 M GA in EtOH, 6 hr, ambient temperature

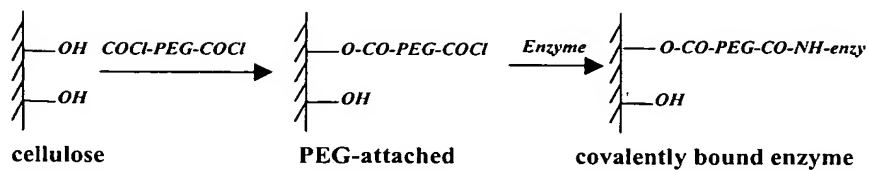
FIG. 26

A



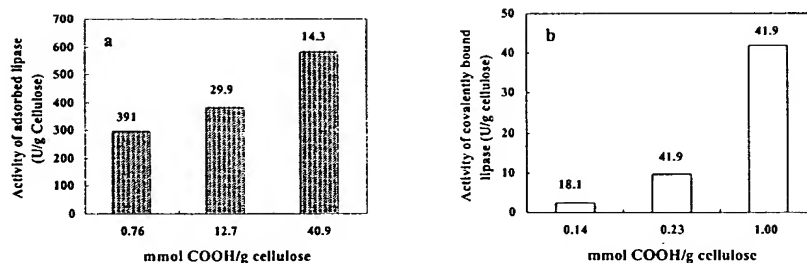
*Surface grafting of polyelectrolyte and subsequent enzyme adsorption*

B



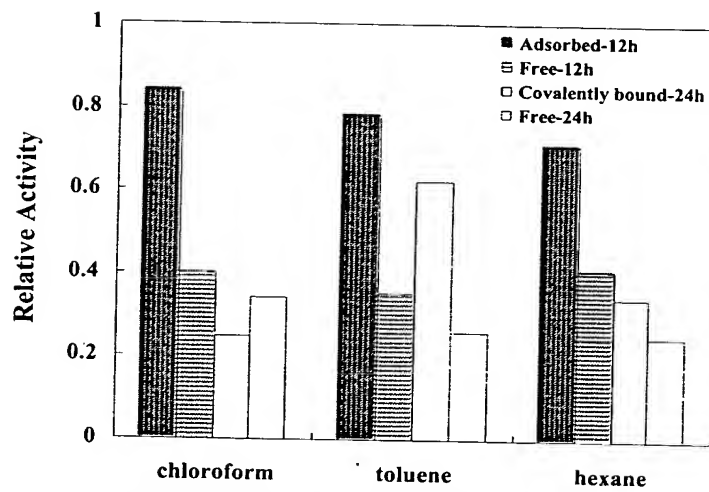
*Attachment of PEG diacylchloride and subsequent enzyme binding*

FIG. 27



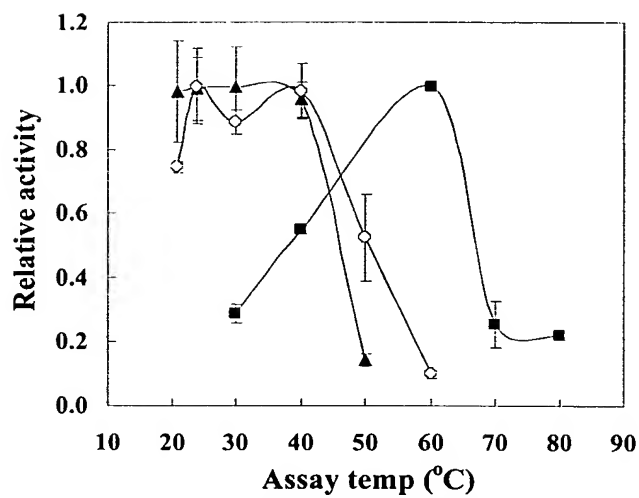
Effect of carboxylic acid quantity on the activity of bound lipase: (a) adsorbed on PAA-grafted ( $[AA]/[Ce(IV)]=120$ ); (b) covalently bonded on PEG-grafted cellulose fibers.

FIG. 28



*Relative activity of free and cellulose fiber bound lipase (pH=8.5, 30°C) following exposure to organic solvents.*

FIG. 29



Relative activity (pH 8.5) of free lipase (○) and bound lipase on PAA-grafted (▲) and PEG-grafted (■) cellulose fibers at various temperatures.

FIG. 30



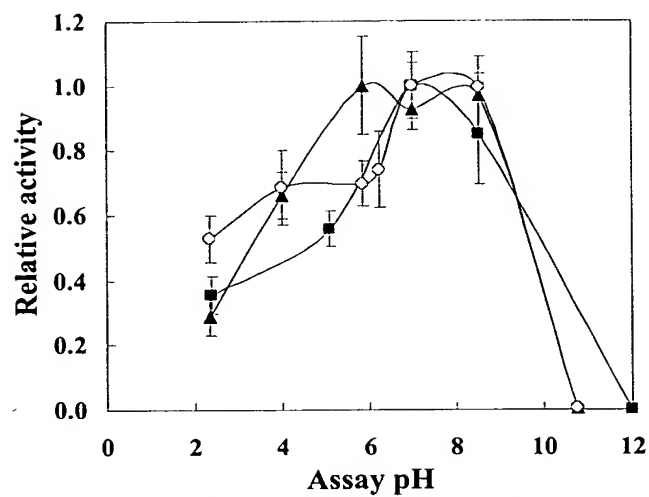
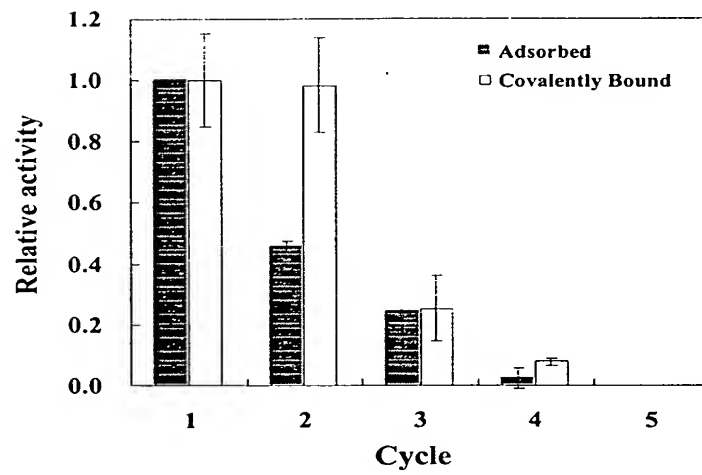


Fig. 31. Relative activity (30°C) of (○) free lipase and (▲) adsorbed lipase on PAA grafted (■) covalently bound lipase on PEG grafted cellulose fibers under various assay pHs

FIG. 31



*Cyclic activity (pH 8.5, 30°C) of bound lipase on cellulose fibers.*

FIG. 32